Sustainable Cities and Society 48 (2019) 101531

Contents lists available at ScienceDirect

Sustainable Cities and Society

journal homepage: www.elsevier.com/locate/scs

Towards a resilience management guideline — Cities as a starting point for societal resilience

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ARTICLE INFO

Keywords:
Resilience
City resilience
Urban resilience
Cities
Co-creation process
Guideline

ABSTRACT

Unexpected crises and risks affect the urban population. Critical infrastructure dependency, climate change and social dynamics have captured the attention of city decision makers across different disciplines, sectors, and scales. Addressing these challenges mandates an increase in resilience. This article presents the development of the novel European Resilience Management Guideline (ERMG) developed by the European H2020 Smart Mature Resilience (SMR) project. It encompasses five supporting tools for city resilience. The purpose of this article is threefold.

First, it describes the extensive co-creation methods used to establish, validate and test the five ERMG tools as collaborations among seven city stakeholders and researchers in Europe. Second, it explains concisely the features of each tool and its use and applicability in the city resilience building process. Third, it shows how EMRG supports strategic management in encouraging the visibility of risk dependencies, identifying vicious loops and potential cascading effects, and promoting collaboration between stakeholders to share resources. The article concludes with a discussion of SMR standardization activities to support the transfer of these research results to wider audiences. It covers guidance on local resilience planning and supporting efforts in building and operationalizing resilience at the city level.

1. Introduction

Today's urban environments are under pressure to cope with combinations of climate change, old and new infrastructure and technologies, continuously changing demographics, political unrest and varying municipal and regulatory practices. Furthermore, these complex networks of interacting physical, social and economic subsystems are still expanding, and projections indicate that 60% of the world's population will be urbanized by 2030 (WHO, 2017), creating a need for increased capacity of urban critical infrastructures (CIs) such as water, telecommunications, energy, and transport systems. The increasing urban complexity and population pressures create significant challenges in understanding the dependencies and interdependencies between these systems and subsystems (Rinaldi, Peerenboom, & Kelly, 2001). New complex cascading failures may stem from unanticipated or emergent system characteristics as they develop in an incremental and ad hoc fashion. For example, the United States electricity blackout in 2003 showed how in functionally interdependent networks, a small failure in

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https://doi.org/10.1016/j.scs.2019.101531
Received 27 July 2018; Received in revised form 2 March 2019; Accepted 1 April 2019
Available online 03 April 2019
2210-6707/ © 2019 Published by Elsevier Ltd.

one network can lead to catastrophic consequences (Bashan, Berezin, Buldyrev, & Havlin, 2013).

Addressing questions on how the impact of events can be managed requires a multi-disciplinary approach across city sectors. For example, cities are highly dependent on CI services, and disruptions that occur in these CIs might have a profound effect on the city's ability to sustain normal functions, affecting the community at large. Not only is there a need to establish a holistic risk-assessment framework across the infrastructures to support cross-sector priorities, but these effects must also be seen in a wider city context. For example, how do organizations manage their infrastructure and variations in risk perception between stakeholders (Brown, Seville, & Vargo, 2017)? How will critical city services be affected (Boyes, Isbell, & Watson, 2014)? How will citizens be affected (Hatvani-Kovacs, Belusko, Skinner, Pockett, & Boland, 2016)? If interdependencies and vulnerabilities are not understood and analyzed, unanticipated consequences and cascading failures may potentially occur, even when crises are expected. Furthermore, preparing adequate response to unpredicted crises is also a challenge since some of the predefined procedures might be unavailable.

The notion of resilience, the ability of complex systems to adapt to changing conditions, provides a framework for addressing such challenges. Resilience expresses the idea that the natural world is complex, dynamic, highly specific, and ever-changing (Whittington & Young, 2013). Building city resilience thus, requires a holistic approach that goes beyond reliable technology, including an understanding of dependencies across city services, potential vulnerabilities and cascading effects, and cross-organizational resilience and collaborative efforts.

This paper presents the approach followed in the Smart Mature Resilience (SMR) project funded by the H2020 program. The overall aim of the SMR project is to develop a European Resilience Management Guideline (ERMG), an operational framework for cities that provides guidance on local resilience planning and supports their efforts in building resilience. The ERMG consists of five different tools, which are intended for use by practitioners to provide guidance and training, apart from supporting municipalities and their most relevant stakeholders in implementing an integrated management system that enhances city resilience. The five tools are: 1) a Maturity Model, 2) a Risk Systemicity Questionnaire, 3) a Resilience Information Portal, 4) a Resilience Building Policies Tool and 5) a City Resilience Dynamics tool. The developed guideline provides a holistic approach to city resilience by supporting strategic management in encouraging visibility of risk dependencies, vicious loops, and potential cascading effects and promoting collaboration between stakeholders in resource sharing. General requirements for all tools supporting the ERMG collected from the city representatives, highlighted the importance of the tools' user-friendliness and usability. The tools should be able to minimize gaps in the mechanisms, indicators, policies and methods and replace procedures that are currently being used in cities.

The paper is structured as follows: Section 2 presents a literature review of the existing research on city resilience. Section 3 describes the co-creation methodologies used in SMR to gather information to develop the tools included and integrated within the ERMG. Section 4 presents in more detail the five tools, which operationalize the guideline. Section 5 describes how the tools were integrated into the ERMG. Finally, Section 6 states the main conclusions and explains how standardization of the guideline will support the application and sharing of the guideline among cities in Europe and beyond.

2. State of art

In recent years, the concept of city resilience has become the most prominent term for dealing with shocks and stresses that affect cities (Lu & Stead, 2013). The concept of resilience has become widely adopted in both policy and strategic reports as well as in academic studies (Kontokosta & Malik, 2018; Weichselgartner & Kelman, 2014). However, there is still a lack of consensus and unification of key concepts (Meerow, Newell, & Stults, 2016; Rankin et al., 2016). In fact, each domain has its own definition of resilience based on their particular characteristics (Weichselgartner & Kelman, 2014). Within the scope of this article, city resilience is defined as "*the ability of a city or urban region to resist, absorb, adapt to and recover from acute shocks and chronic stresses to keep critical services functioning, and to monitor and learn from on-going processes through city and cross-regional collaboration, to increase adaptive abilities and strengthen preparedness by anticipating and appropriately responding to future challenges*" (Smart Mature Resilience, 2016a, pp. 8).

Another important challenge is the transition from theory to practice, that is, making resilience tangible and practical for cities (Kontokosta & Malik, 2018; Meerow et al., 2016). The growing political interest in resilience approaches to tackle future challenges is an important first step. However, governments and practitioners need support and guidance in order to be able to build resilience in an optimal and effective manner (Weichselgartner & Kelman, 2014).

Several resilience initiatives have focused on improving city resilience by developing guidance frameworks. Some of them focus on only one hazard such as the SPUR framework developed by San Francisco Planning and Research Association. SPUR proposes policies and mitigation plans for buildings only in case of earthquakes (SPUR- San Francisco Planning & Urban Research Association, 2009). In contrast, other frameworks focus on a multi hazard approach covering not only technical aspects but also social and economic factors. The Rockefeller Foundation's 100 Resilient Cities, for example, developed a City Resilience Framework that defines resilient systems as those that have the following qualities: robustness, redundancy, flexibility, resourcefulness, inclusion, and integration. In addition, a city must have a combination of effective city leadership, good infrastructure, social cohesion, collective identity and relative prosperity (Rockefeller Foundation & ARUP, 2014). United Nations Office for Disaster Risk Reduction (UNISDR) developed the Hyogo framework (UNISDR (United Nations International Strategy for Disaster Reduction), 2005) and its successor, the Sendai Framework (UNISDR (United Nations International Strategy for Disaster Reduction), 2015), to reduce disaster risks and losses and to strengthen assets in cities for Disaster Risk Reduction. To achieve this objective, the Sendai Framework defines four priority actions that include understanding disaster risk, strengthening disaster risk governance, investing in resilience and enhancing disaster preparedness. The National Institute of Standards and Technology (NIST) has also developed the Disaster Resilience Framework. It provides communities with a methodology to plan for resilience by prioritizing improvements in buildings and infrastructure systems based on their importance in supporting social institutions and economic functions in the community (NIST (National Institute of Standards & Technology), 2016). However, current frameworks have been criticized for being of limited relevance to local realities and their lack of understanding of the complex risk landscape of today's cities due to the existing interconnections between systems (Oxley, 2015).

From a quantitative point of view, several studies have been published addressing empirical assessment methods. Kammouh, Dervishaj, and Cimellaro (2018) presents a quantitative method to assess the resilience at the country level. Kontokosta and Malik (2018) present the Resilience to Emergencies and Disaster Index (REDI), which evaluates the resilience capacity of cities and provides a measure of performance according to four resilience categories: social infrastructure, physical infrastructure, economic strength, and environmental conditions. On the other hand, PEOPLEs considers seven dimensions in its evaluation: population, environment, organized governmental services, physical infrastructures, lifestyle and community competence, economic development and social-cultural capital (Renschler et al., 2010), while BRIC covers the following six domains: social, economic, housing and infrastructure, institutional, community and environmental (Cutter, Ash, & Emrich, 2014). However, these empirical methods are associated with major challenges, such as the inclusion of theoretical bases,

multivariate assessment, indicator weighting, and validation (Asadzadeh, Kötter, Salehi, & Birkmann, 2017).

Therefore, despite the efforts of academia and different organizations, there is still a large gap in resilience operationalization when going from theory to practice, making resilience tangible and practical for cities (Collier et al., 2013; Serre, Barroca, Balsells, & Becue, 2018). Currently, there are limited examples of the effective sequential steps that cities should follow to involve stakeholders in the resilience-building process and to improve the city resilience level (Weichselgartner & Kelman, 2014). In this regard, there is a lack of roadmaps and guidelines for operationalizing the resilience building process.

The contribution of this research is the development of an European Resilience Management Guideline (ERMG) that guides cities in the resilience operationalization process. This Guideline makes use of five strategic resilience-building tools to describe a journey with sequential steps, in which cities and municipalities start out from different points depending on their varying stages of resilience maturity. In a nutshell, the Guideline provides guidance and consultancy services to cities and local governments for assessing their local resilience status; It can be used to set measurable targets in collaboration with local stakeholders, deploying the five tools to help the city build on local resilience and progress within the different stages of maturity. It defines an operational framework that provides guidance for training and supporting municipalities and relevant stakeholders in implementing an integrated management system that enhances city resilience.

3. Methodology

This research has been developed under the umbrella of the European SMR project. The consortium comprises not only academic entities (TECNUN-University of Navarra, University of Strathclyde, CIEM-University of Agder, and Linköping University) and consultancies (ICLEI and DIN), but also city representatives (Bristol, Glasgow, Kristiansand, Riga, Rome, Donostia-San Sebastian and Vejle), who are proactively involved in developing the tools. With the city representatives on board, who will be the end users of the ERMG and its toolkit, it was possible to gather useful information on their outlooks, concerns, requirements and preferences. Taking advantage of this, the SMR project has adopted a co-creation approach. Co-creation refers to the active involvement and engagement of stakeholders in the production of knowledge (Voorberg, Bekkers, & Tummers, 2015).

The SMR results were developed through a multi-methodological procedure and a co-creation approach that involved a variety of experts from local, regional and national governments, academic and scientific entities, and public and private companies. All of them are knowledgeable about the resilience-building process with regard to critical infrastructure interdependencies, climate change adaptation and social dynamics. In turn, this co-creation approach facilitated mutual learning and the establishment of relationships, trust between the different stakeholders taking part in this process, and ensures the usefulness and reliability of the results (Frantzeskaki & Kabisch, 2016).

In this section, the tools development procedure is described, mentioning the different co-creation methodologies used in the process (see Fig. 1). An average of 15 multidisciplinary experts working in different city sectors were involved in each activity in order to guarantee that the tools were designed with the input of all relevant stakeholders in the context of city resilience.

Additionally, each tool was tested in three pilot implementations in three different cities, Kristiansand (Norway), Donostia-San Sebastian (Spain) and Glasgow (UK), with the aim of improving and validating their usefulness, reliability and trustworthiness in addition to validating the flexibility of each tool to be adapted to any European city.

3.1. Resilience Maturity Model (RMM)

The co-creation process to develop the Resilience Maturity Model was divided into two phases. In the first phase, four workshops with experts in the field of resilience were held to identify valuable information to understand the evolution of the resilience-building process. These workshops used the Group Model Building (GMB) collaborative methodology that enables fragmented knowledge, initially residing in the minds of different agents, to be integrated into aggregated knowledge (Richardson & Andersen, 1995). This methodology is based on workshops in which multi-disciplinary experts work jointly on the problem using specific exercises that support efficient collaboration. The information gathered in each workshop is analyzed and used as the basis for the next workshop. This iterative process and the participation of multi-disciplinary experts from different backgrounds increases the value of the input provided by participants.

The two day workshops were held in four city partners (Riga, Bristol, Rome and Vejle). City representatives from the seven city partners and from different areas such as environmental management, infrastructure protection and social issues took part in the workshops. The first workshop day focused on gathering information for RMM development using GMB methodology, while the methodology used in the second day was focused on the development of the Risk Systemicity Questionnaire using a Group Support System (see Section 3.2). The first workshop, held in Riga, addressed the challenge of critical infrastructure dependency (Smart Mature Resilience, 2016a). The second workshop, held in Bristol, focused on climate change (Smart Mature Resilience, 2016b). The third workshop, held in Rome, focused on social dynamics (Smart Mature Resilience, 2016c). Finally, the fourth workshop, held in Vejle, focused on studying the existing interdependencies between the challenges already addressed in the previous workshops (Smart Mature Resilience, 2016d). Based on this

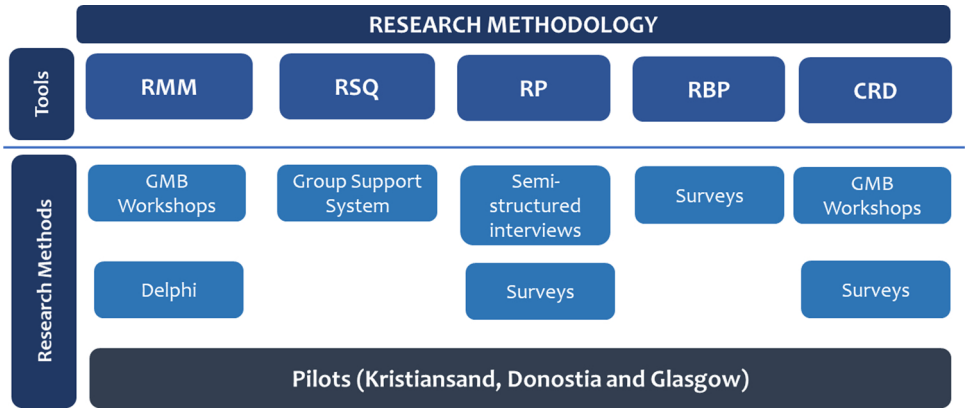

Fig. 1. Summary of the co-creation methods used to obtain information to develop each of the tools.

information, a preliminary version of the RMM was developed defining the maturity stages and the policies to implement in each maturity stage.

In the second phase, the consolidated RMM was developed using a two round Delphi process in which 40 experts participated. Delphi methodology was selected since it is well-suited to consensus-building processes related to a complex problem through a systematic and iterative process using a set of questionnaires to collect data from a panel of selected experts (Linstone & Turoff, 1975; Okoli & Pawlowski, 2004). The purpose of the first round was to validate the statements that describe the five maturity stages of the SMR MM. In the second round of the Delphi process, participants were asked to classify the resilience-building policies in the maturity stages. Based on the information gathered during this Delphi process, the descriptions of the maturity stages were validated and the implementation order of the policies was determined by establishing the starting stage and the ending stage of each policy.

3.2. Risk Systemicity Questionnaire (RSQ)

The RSQ is a decision support tool that presents multiple interconnected risk scenarios to city users to help them prioritise their limited resources with respect to risk mitigation. To gather content for the tool, the views of city participants as experts about the risks cities face in the future were gathered. The collected risks were not assumed to be independent of each other and so, it was also necessary to collect views about the causal relationships between risks and also elaborate their ramifications. *Group Explorer*, a Group Support System (GSS), was used to support the series of interactive workshops with city participants (Lewis, 2010).

Group Explorer is a computer software by which i) each participant is provided with a computer console through which they can 'speak' to a projected display screen that shows all contributions ii) participants can express their views at the same time (rather than only one person talking) iii) full anonymity of contributions is guaranteed, and iv) the statements submitted by participants can be organized as a causal map (network of interacting statements). *Group Explorer,* as a Group Support System, is designed to promote high levels of group productivity, and also allows the facilitator of the workshop to monitor users' contributions and so manage the collection of different perspectives.

As mentioned in Section 3.1, the sessions included four one-day workshops during which the facilitator encouraged city stakeholders, as workshop participants, to express their views/expertise on risks that cities may face in the future with respect to the three main topics covered by the SMR project (Critical Infrastructure, Climate Change, Social Issues) and how these risks may impact each other. City stakeholders used their individual computer consoles to enter risks in the form of short statements and to add causal links, which represent the impact of one risk on another (Pyrko, Eden, & Howick, 2019). The growing network of contributed risks was displayed on the shared projected public causal map. As the collection of expertise developed, the *Group Explorer* software enabled participants to express their judgments on, for example, the relative significance of risk scenarios (clusters of linked statements) by engaging in anonymous voting and rating exercises. The causal map of risks was then elaborated during two further two-hour meetings. The resulting map and the risk scenarios, which emerged from the map, formed the basis of the development of the RSQ.

From the map, scenarios were firstly selected by attention to vicious cycles, because they are least often perceived by managers, and secondly by attention to those regarded as of most importance to the cities participating in the project. Some of the risk scenarios were also validated through published literature.

An Excel-based interactive set of questions was developed based on the risk scenarios. The intention was that city stakeholders use the tool as a group with its main purpose being to encourage focused, interdisciplinary conversations about those risks that are of greatest concern to the city.

3.3. Resilience Information Portal (RP)

The aim of developing a portal for information sharing and collaboration was fixed upfront as a goal of the project. The actual requirements, however, needed to be identified as part of our work. Therefore, an iterative, incremental and evolutionary development process was employed, in which the initial set of requirements was based on design principles. These design principles were derived from the needs of the city partners.

Semi-structured interviews were conducted with experts in city resilience from different backgrounds allowing an open discussion on different topics (Myers & Newman, 2007). Experts from each of the seven partner cities were interviewed; the number of interviews ranged from one to five per city. Topics were chosen based on an analysis of the literature and domain knowledge in Web portals and online communication and, were used as initial requirements for the Resilience Portal. The requirements were useful for determining the focus of the semi-structured interviews, thus facilitating valuable discussion with different experts on city resilience.

The interviews aimed to understand state of the art communication activities in each city, e.g., how cities share information and knowledge with their stakeholders. Moreover, the interviews were structured according to the insights gained from an online pre-questionnaire aimed at better understanding cities' requirements regarding information system utilization and communication activities. This questionnaire was distributed beforehand to identify communication challenges and relevant stakeholders.

Researchers performing the interviews followed an interview guideline and had access to a list of suggested questions. In general, the interviews applied a semi-structured approach that allowed for an open discussion around the question topic. The interviews were audio-recorded and transcribed according to the guideline.

In total, we conducted 19 detailed interviews. Synthetizing the findings lead to the design goals for a resilience information portal, which form the goals of development as described later in this article. Moreover, the detailed insights from the interviews were also the foundation for the initial set of requirements.

3.4. Resilience Building Policies (RBP)

Surveys were used to collect case studies from the seven cities participating in the project regarding different resilience building initiatives that were being conducted at each of the cities. These would be used to provide practical information about the implementation of the policies contained in the RMM. A survey consists of a systematic and standardized approach to collect information from a group of people through questionnaires (Forza, 2002).

For ease of use, research partners agreed that the case studies should (i) be no longer than one A4 page and (ii) contain a picture where possible. In most instances, the cases were reported verbally by the cities and then drafted by the interviewer. The draft was then checked by the city. Typically, the drafts were completed with further details and editing as the cities checked their memories.

The information gathered directly impacted the design principles presented later in the article. Moreover, they have been the foundation for the incremental and iterative process of deriving functions for the Resilience Information Portal.

3.5. City Resilience Dynamics Tool (CRD)

The City Resilience Dynamics tool was developed using System Dynamics modelling methodology and an easy to use Graphical User Interface to facilitate the interaction between the user and the model.

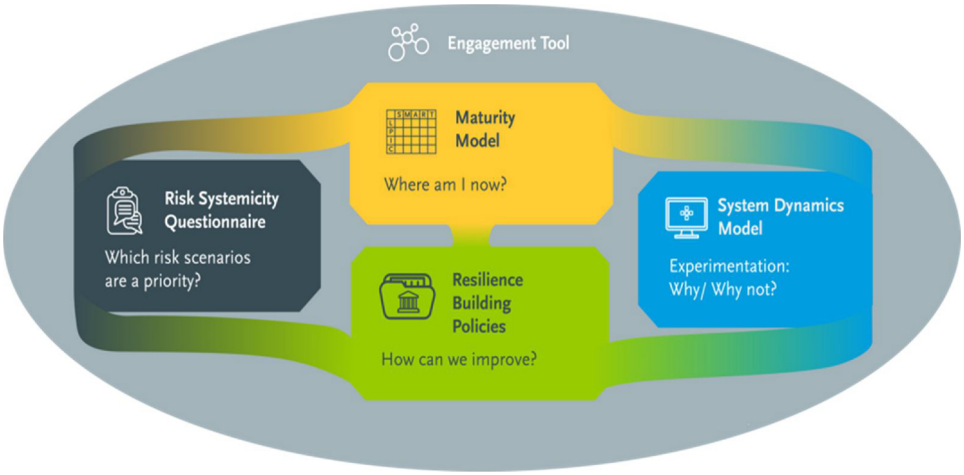

Fig. 2. Smart Mature Resilience Toolkit.

System Dynamics is a modelling methodology that focuses on analyzing the underlying structure that generates the behavior of complex systems (Richardson & Pugh, 1981; Sterman, 2000). An iterative process has been used to develop this tool through two validation workshops and two surveys with experts.

Firstly, the precedence relationships among the policies defined in the RMM were determined through a survey to city representatives from the seven city partners. The precedence relationships define the policies that need to be implemented previously in order for a policy to be effective in its implementation. The participating experts, with resilience building and crisis management background, were asked to assess from 0 to 5 (0 representing no relationship and 5 a strong relationship) how the policies were related to each other regarding the precedence dependencies. That is, in order for a policy to be effective in its implementation, the precedence policies should have been implemented previously. Based on this information a preliminary City Resilience Dynamics tool was developed.

This preliminary version of the tool was iteratively improved through the pilot workshops with experts carried out in the city of Donostia-San Sebastian in Spain, and the city of Glasgow in the UK. In both workshops the GMB methodology was used. All participants were divided into groups and each group had a moderator and a recorder to guide the experts with the exercises. The participants got time to experiment and better understand the features of the tools. Finally, the participating experts were asked to use the tool based on their practical experience with the aim of getting a target in the resilience level. These exercises allowed participants to understand how the tool can help them in understanding the resilience building process and can be used as a decision-making tool. The participating experts were asked to assess the usability of the tool, the reliability and trustworthiness of the results provided by the tool and the flexibility of the tool to be adapted to any city.

Finally, a survey with city representatives from seven city partners was carried out to estimate the values of the main parameters of the underlying System Dynamics model. The participants were asked to assess, using as a reference the characteristics of their own city, the main parameters of the model. As a result, an improved version of the City Resilience Dynamics tool was developed.

4. The city resilience toolbox

The co-creation approach of the SMR project enabled gathering information from cities in order to understand what they expect from the European Resilience Management Guideline (ERGM). This information was crucial for the development of the five tools that support the ERGM, whose aim is to contribute to the city resilience-building process.

As previously mentioned, the five strategic resilience tools developed within the SMR project are (Fig. 2): 1) a Resilience Maturity Model, 2) a Risk Systemicity Questionnaire, 3) a Resilience Information and Communication Portal, 4) Resilience Building Policies and 5) a City Resilience Dynamics Model.

4.1. Resilience Maturity Model (RMM)

4.1.1. Aim of the RMM

The RMM helps to identify the ideal path for the evolution of the resilience building process from an initial stage to a more advanced stage, passing through a number of intermediate stages. Actually, it provides an optimum path to increase the resilience level of cities. Initially, the RMM enables, on a strategic level, the development of an assessment of a city's current resilience status and the identification of areas for improvement. And then, based on this initial assessment, a city will use the RMM to define the strategy needed to increase their resilience level, on the basis of the RMM policies. The RMM also aids reflection since it provides a holistic overview of the resilience-building process and helps end-users to understand resilience as a multi-dimensional objective.

4.1.2. Application of the RMM

The RMM is presented in the form of a matrix consisting of five maturity stages and four dimensions that serve to classify policies and city stakeholders in the different stages and dimensions (Hernantes, Maraña, Gimenez, Sarriegi, & Labaka, 2019). Fig. 3 shows its structure.

The elements of the RMM are the following:

a. **Maturity stages (acronym SMART)**: The RMM defines five sequential maturity stages (Starting, Moderate, Advanced, Robust, and verTebrate) that cities pass through, starting from their initial efforts in the resilience-building process and ending with the achievement of resilience excellence. ·
b. **Dimensions (acronym LPIC) and sub-dimensions**: the policies included in the RMM have been classified according to four pillars or dimensions. Each dimension is also split into several sub-dimensions as follows:

- Dimension 1: Leadership & Governance
  - Municipality, cross-sectorial and multi-governance collaboration
  - Legislation development and refinement
  - Learning culture
  - Resilience action plan development
- Dimension 2: Preparedness

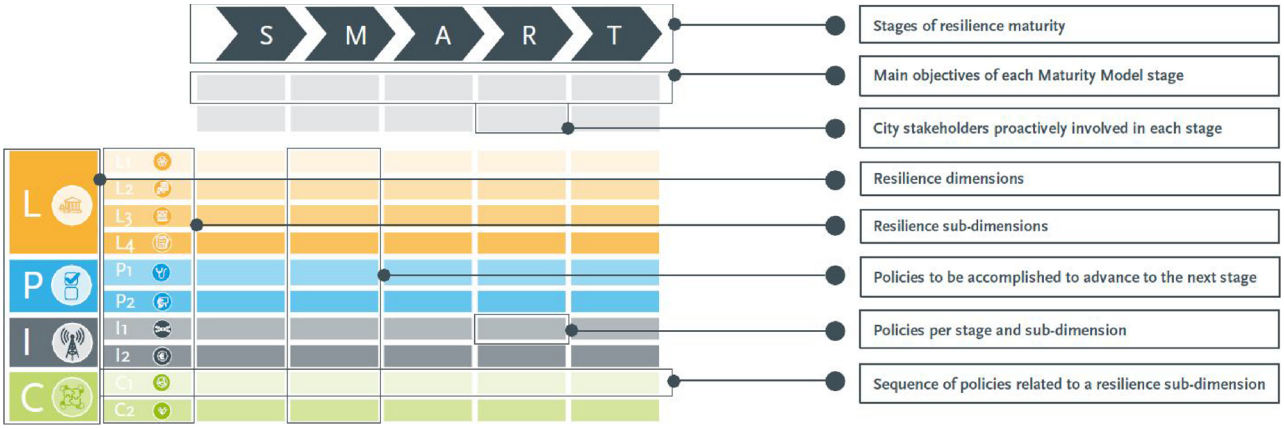

Fig. 3. Structure of the Resilience Maturity Model.

- Diagnosis and assessment
- Education and training
- Dimension 3: Infrastructures & Resources
  - Reliability of CIs and their interdependencies
  - Resources to build up resilience and response
- Dimension 4: Cooperation
  - Development of partnerships with city stakeholders
  - Involvement in resilience networks of cities

c. **Policies**: For each dimension and sub-dimension, a set of policies has been proposed to move a city forward from one maturity stage to a more advanced one. The RMM is proposing a sequential order to develop these policies so that the use of resources is more effective. The wide scope of some of the policies means that they cannot be fully implemented in one specific stage, so they need to be implemented throughout different maturity stages.

d. **Relevant Stakeholders**: The RMM also provides information about the stakeholders that need to be involved in a proactive way in each maturity stage. In the early stages of the RMM few stakeholders are proactively involved in the city resilience-building process. As cities move forward through the RMM stages more city stakeholder groups will be involved. In the last stage all of the city stakeholders will be contributing to the city resilience-building process.

e. **Indicators**: The aim of the indicators is to provide cities with metrics for discussion and analysis of the different policies developed in the resilience building process, giving an indication of positive behaviors and supporting the continuous development that is made towards resilience building policies.

4.2. Risk Systemicity Questionnaire (RSQ)

4.2.1. Aim of the RSQ

The Risk Systemicity Questionnaire (RSQ) supports cities in undertaking risk assessment by encouraging them to think, and engage in a focused discussion across organizational silos, about how risks can interact with one another and so create possible complex ramifications that can create multiple risk scenarios. It is a decision support tool to help cities prioritize their limited resources with respect to risk mitigation.

Effective risk assessment can be considered an essential element in developing city resilience, since resilience "…requires actively understanding the risk landscape, determining where those risks are best owned and managed, strengthening the components of the system that help to face those risks, and understanding how the interrelatedness of these components affects system functioning" (van der Vegt, Essens, Wahlström, & George, 2015).

The EU guidelines on Risk Assessment and Mapping Guidelines for Disaster (European Commission, 2010) recommend that cities, regions and governments use the risk register as an approach to risk assessment. While such a register provides a structure for consideration of the risks that may be faced, it suffers from a number of limitations (Ackermann, Eden, Williams, & Howick, 2007). One such limitation is that it considers risks as independent from one another. However, the risks which cities face are usually the consequence of complex interactions between many factors which can often reinforce one another, and form self-reinforcing feedback loops – vicious cycles (Fig. 4). These interactions can lead to non-obvious, counter-intuitive, unintended consequences that may be difficult for cities to anticipate (Eusgeld, Nan, & Dietz, 2011; Rinaldi et al., 2001). Risk systemicity can be difficult to understand due to the complexity that can result when considering the interactions between many risks. The RSQ, presented in this section, allows cities to

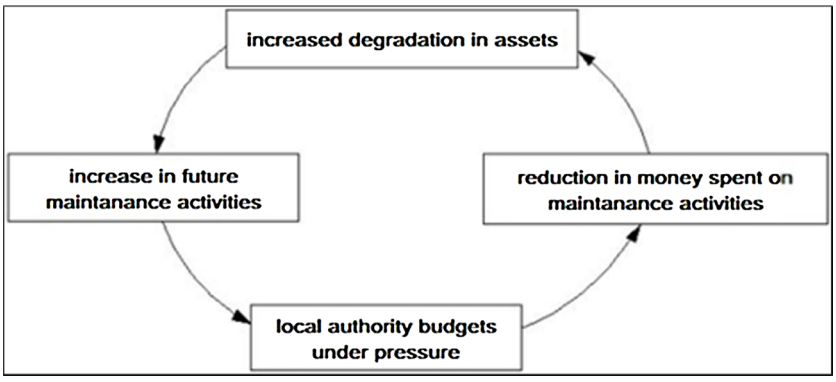
increased degradation in assets
increase in future maintanance activities
reduction in money spent on maintanance activities
local authority budgets under pressure

Fig. 4. An example of a vicious cycle from the RSQ.

operationalize risk systemicity in their own settings, and thereby make risk systemicity an integral part of their everyday risk assessment processes.

4.2.2. Application of the RSQ

The RSQ has been designed as an interactive set of questions, which city stakeholders typically complete in a group. The main purpose of the tool is to encourage focused, interdisciplinary conversations about those risks that are of greatest concern to the city. The content of the RSQ was derived from material gathered using a Group Support System described in Section 3.2. The risk scenarios contained in the RSQ are grouped into ten risk areas that became significant as the data was analyzed, where each risk area contains 6–15 significant risk scenarios. The RSQ considers risk scenarios as vicious cycles (Fig. 4) and causal chains (Fig. 5). For each risk scenario, which is presented in both text and picture form, users are asked to provide a response with respect to the likelihood of occurrence of that scenario in their own city (Fig. 6). The user is presented with a number of options, and asked to choose one of the following with respect to the given scenario; 'highly probable', 'probable/possible', 'improbable', 'I don't know but someone else (in my organization) knows, and 'we don't know'. This response determines the potential for occurrence of a risk scenario. The impact of the risk scenario is determined by a pre-determined weight. This weighting is based on the extent of ramifications of the scenario. The impact of the risk scenario and its potential for occurrence are combined so that, upon completion of the RSQ, the user is presented with a prioritization, which may then be used as a focus for developing mitigation strategies.

An important aspect of the RSQ is that risk scenarios between different topics interact with one another. This feature of the RSQ emphasizes the importance of considering the interdependencies between bundles of risks (scenarios) as well as individual risks. The interacting scenarios can also capture chains of arguments, which cross over between the different RSQ topics. Some scenarios also act as triggers for other scenarios. When a trigger scenario is answered as being 'unlikely', then the scenarios that would otherwise follow on from that 'unlikely' scenario are disabled and effectively hidden from the RSQ. Since the prioritization of scenarios takes into account all completed scenarios from each topic of the RSQ, the hidden and unconsidered scenarios are excluded from this prioritization.

In order to address the imposed threats, risk mitigation suggestions, which were collected from partner cities, were also included in the RSQ to allow a city to consider strategies for improving their resilience through policy implementation. In addition, for each scenario, users can also save comments that may emerge from discussion about both the scenario and the risk mitigating actions. Implementation of the RSQ in cities evidenced that the ability to capture comments and thus tailor the RSQ content to the needs of an individual city is an important feature of the RSQ.

4.3. Resilience Information Portal (RP)

4.3.1. Aim of the RP

The RP aims to build a collaborative environment in order to facilitate awareness and engagement among key partners in resilience building (Sakurai, Majchrzak, & Latinos, 2017). It enables cities to

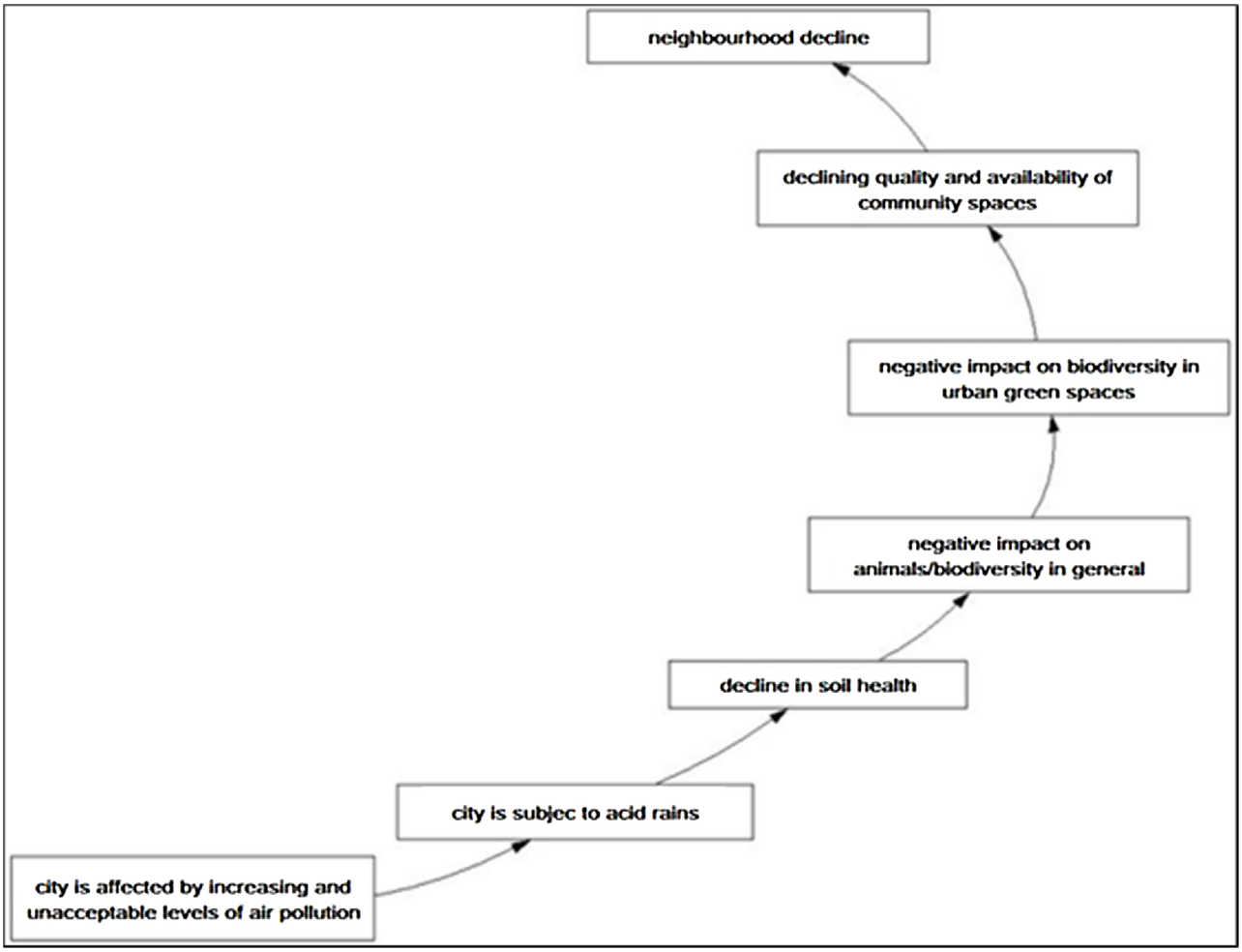
neighbourhood decline
declining quality and availability of community spaces
negative impact on biodiversity in urban green spaces
negative impact on animals/biodiversity in general
decline in soil health
city is subjec to acid rains
city is affected by increasing and unacceptable levels of air pollution

Fig. 5. An example of a risk systemicity scenario from the 'infrastructure' tab.

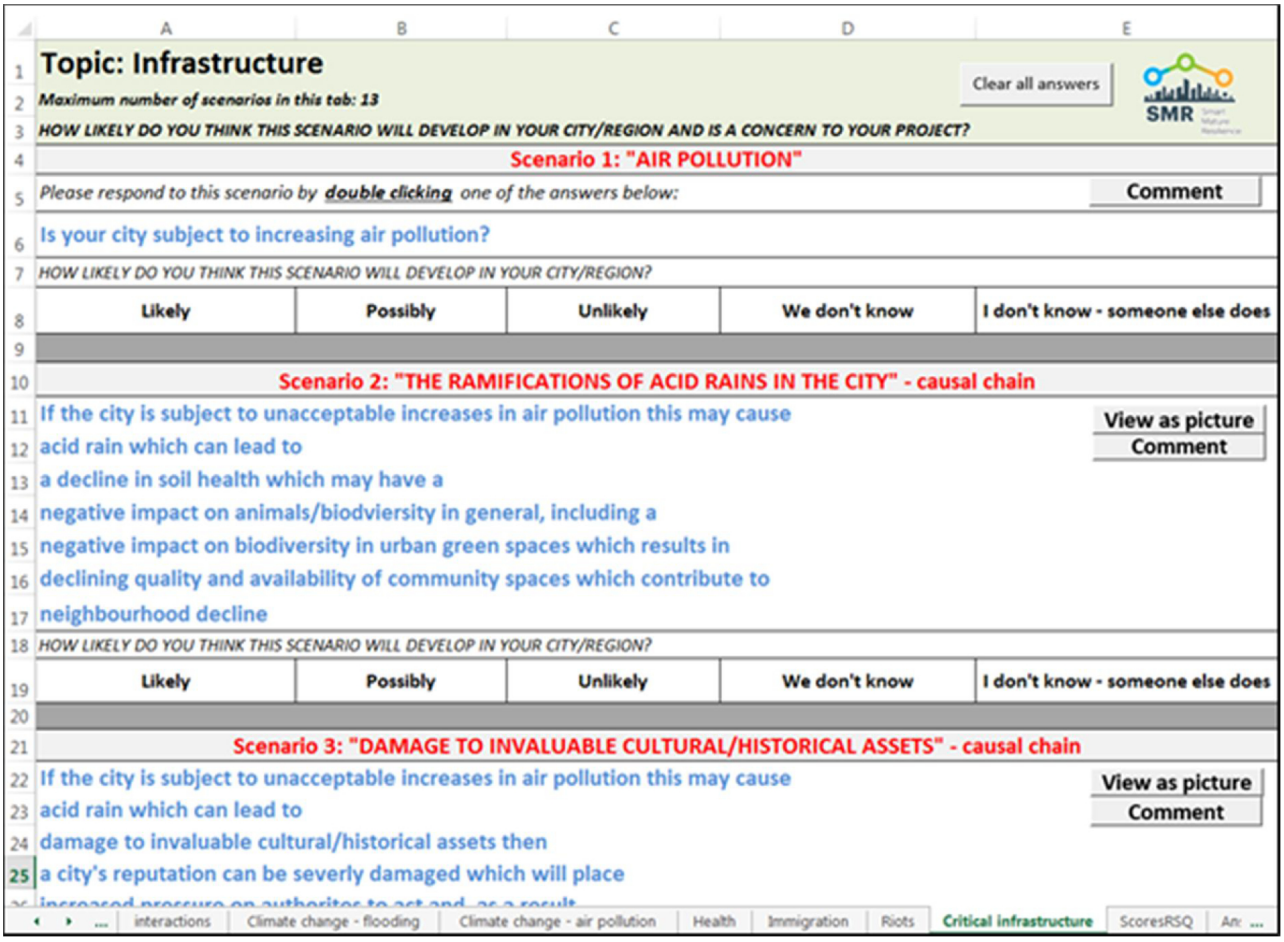
Topic: Infrastructure
Maximum number of scenarios in this tab: 13
Clear all answers
SMR
HOW LIKELY DO YOU THINK THIS SCENARIO WILL DEVELOP IN YOUR CITY/REGION AND IS A CONCERN TO YOUR PROJECT?
Scenario 1: "AIR POLLUTION"
Please respond to this scenario by double clicking one of the answers below:
Comment
Is your city subject to increasing air pollution?
HOW LIKELY DO YOU THINK THIS SCENARIO WILL DEVELOP IN YOUR CITY/REGION?
Likely
Possibly
Unlikely
We don't know
I don't know - someone else does
Scenario 2: "THE RAMIFICATIONS OF ACID RAINS IN THE CITY" - causal chain
If the city is subject to unacceptable increases in air pollution this may cause
acid rain which can lead to
a decline in soil health which may have a
negative impact on animals/biodviersity in general, including a
negative impact on biodiversity in urban green spaces which results in
declining quality and availability of community spaces which contribute to
neighbourhood decline
View as picture
Comment
HOW LIKELY DO YOU THINK THIS SCENARIO WILL DEVELOP IN YOUR CITY/REGION?
Likely
Possibly
Unlikely
We don't know
I don't know - someone else does
Scenario 3: "DAMAGE TO INVALUABLE CULTURAL/HISTORICAL ASSETS" - causal chain
If the city is subject to unacceptable increases in air pollution this may cause
acid rain which can lead to
damage to invaluable cultural/historical assets then
a city's reputation can be severly damaged which will place
View as picture
Comment
interactions
Climate change - flooding
Climate change - air pollution
Health
Immigration
Riots
Critical infrastructure
ScoresRSQ

Fig. 6. The 'Infrastructure' tab as part of the RSQ.

improve communication with stakeholders. Through the implementation of the RP, we assume that cities can reflect and – if needed – enhance the parts of the IT and communication strategies that are relevant for resilience. The portal has been designed considering the following six design goals derived from interviews with partner cities and related stakeholders. These goals became the theoretical basis of the RP.

1 *Information Sharing*: refers to daily and emergency communication. The overall objective of communication in the context of the city is to understand the capability of city stakeholders to prevent, respond and recover from crises as well as their ability to allocate resources.
2 *Establish a Communication Structure with stakeholders*: contacting relevant people as quickly as possible is a major concern for cities to ensure operation under normal or emergency conditions.
3 *Engagement and Raising Awareness of Stakeholders, particularly Citizens*: this is the most essential goal for most of the cities. The portal should assure that the information flow between cities and citizens is bidirectional.
4 *Knowledge Sharing*: long-term involvement of citizens and stakeholders requires different types of communication. It is less structured than daily or emergency communication. Opportunities for sharing experiences, risks and best practices should be provided on a proper scale, which can be implemented on local, national, and European level.
5 *Information Sovereignty*: refers to communication challenges associated with security, information confidentiality, handling of documents marked as confidential, and mal-information on social media. Introducing role-based authorization and penetration tests would help to increase information quality.
6 *Usability*: both lack of awareness of information reach and the way to provide appropriate information to users are identified as a communication challenge. All user interfaces on the portal should be designed to ensure high accessibility.

4.3.2. Application of the RP

The core functionalities provided by the RP can be summarized as follows (Majchrzak, Sakurai, & Serrano, 2018):

- It is a publicly available Web-based information system (IS), providing static and dynamic content. While the IS generally is available to anyone through the Internet, it includes restricted content that requires authentication and (content-specific) authorization for access.
- It must aid the provision of typical resilience-related dynamic content, such as contact lists, and offer the possibility to align or even integrate external data sources.
- It must be user-friendly, and editing must be possible even without technical expertise.
- Authentication and authorization for a role-based user concept must be possible.
- Bi-directional communication must be enabled. The portal should support exchange between the city, its stakeholders, and its citizens.
- An “emergency mode” must be provided, allowing only the most relevant (live) information to be shown in the case of a specific threat or emergency.
- Social media must be integrated.

These functionalities can be used as the foundation for the

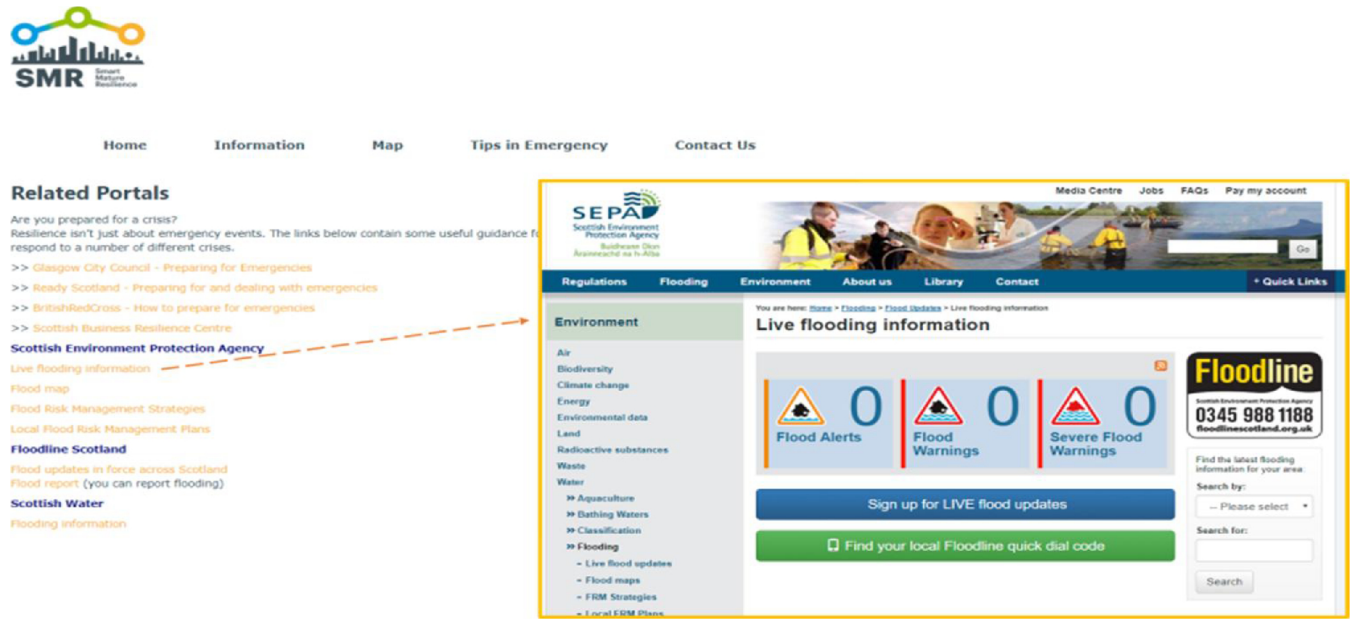

Fig. 7. Glasgow portal- link to the real time surveillance source.

contractual development of a portal, as a starting point for deriving user stories for an agile development process, in order to identify desired or missing aspects of existing municipal IT systems. Besides the core functionalities, additional functionality can be helpful, such as the possibility for a user to customize the portal, the integration of video telephone services, advanced linkage with existing information systems, and social media monitoring.

To allow for flexibility, no recommendations are given with regard to technology (such as programming language and development frameworks) or paradigms (such as development method). From a non-functional perspective, particularly security, usability and ergonomics, accessibility, extensibility, maintainability and scalability need to be addressed. Moreover, a basic level of robustness is required. Based on design goals and functions employed, the portal was developed as a toolbox, which shows ideal functionalities for communication in city resilience. For instance, it can show information required in immediate events, such as which areas to evacuate in the case of flooding (Fig. 7).

4.4. Resilience Building Policies (RBP)

4.4.1. Aim of the RBP

Resilience Building Policies (RBP) complements the strategic priorities in the RMM by providing examples of how these strategic policies have been implemented in practice by cities across Europe. The RBP is a Web-based, interactive tool containing a portfolio of case studies and supporting information. Through integration with the RMM, the RBP serves as a tool to support strategic, long-term thinking about improvement of the resilience level of a city by providing real-life examples to cities that demonstrate how the policies have been implemented in practice. Furthermore, the RBP increases the interactivity and the usability of the Web-based version of the RMM as it enables city users to access additional information that can support the implementation process of the RMM policies. These points have been confirmed through feedback from cities that have implemented the tool. The RPB is thus seen as a promising tool, which provides a practical contribution to the ERMG, particularly by adding value to the future use of the RMM.

4.4.2. Application of the RBP

For the case studies collected from partner cities the structure of the information presented in the RBP tool is as follow:

- Policy description - describes the RMM policy.
- Case studies - lists the relevant case studies assigned to that RMM policy.
- Summary of the case study.
- Further information:
  - City context – the type of cities that may find this policy of interest.
  - A picture illustrating the case study.
  - Goals – what the initiative in question intended to achieve.
  - Cooperation between stakeholders – how different stakeholders worked together to implement the resilience project in question.
  - Outcomes – what was achieved from the initiatives?
- Resources – the resources that were required to implement the project.
- Other links – links to other resources of relevance to the case study.
- Indicators that can be used to evaluate the progress of the implementation of the policy.

4.5. City Resilience Dynamics Tool (CRD)

4.5.1. Aim of the CRD

The City Resilience Dynamics (CRD) tool aims at helping crisis managers to diagnose, explore and learn about the resilience building process. They can use the tool to make decisions and to take the correct actions in the resilience building process. The tool is based on a simulation model developed using the System Dynamics simulation methodology. The simulation model encapsulates the most important aspects of the RMM and helps to encompass the RMM in a training environment for the cities to learn about the path towards improving resilience (Iturriza, Abdelgawad et al., 2017). The model allows the user to try different policy options, identifying the implications of each of them in the resilience improvement process. Furthermore, it allows users to identify the dynamic relationships among the policies, since some policies are predecessors of others. The implementation of some policies is required in order that others have a positive effect when they are implemented. In this regard, the simulation tool can be used to analyze how to get the maximum performance from available resources in order to obtain the maximum level in building resilience.

The CRD is a reflexive tool that helps the user to learn about how the resilience building process works and promotes reflection about what strategy could be more suitable to efficiently use the resources in the resilience building process (Iturriza, Labaka, & Sarriegi, 2017). During the simulation, the training tool provides messages to the users to guide them in the resilience building process and shows them the most efficient path towards improving resilience. In this context, the

CRD tool has been developed to promote awareness among policy makers of the potential counter-intuitive consequences of applying different policies. Ultimately, the training tool has been developed with the aim of providing decision makers with a tool for training, experimenting and understanding real-life scenarios and helping them make appropriate decisions in the resilience building process.

4.5.2. Application of the CRD

The CRD has been designed on the basis of the information defined in the RMM. The user has the option of particularizing the tool to their city's characteristics, establishing its current maturity stage and adapting the main parameters of the tool to the city's own characteristics. Moreover, it can adjust the annual available budget for the resilience building activities. Once the training tool has been adjusted, the user can start experimenting with it.

In the decision page, the user has to determine the strategy to be followed regarding the implementation of the policies. The user has to decide how much resources will be allocated to the implementation process of each policy and also to the maintenance of each policy since, once the policy is fully implemented, some resources are also needed to maintain it over time. When deciding on the strategy, the user has to be aware of the precedence relationships that exist among the policies. If the user decides to allocate some resources to implement a policy but one of its predecessors has not been already implemented, then the selected policy will be ineffective in the resilience-building process and therefore the resources used to implement this policy will be wasted.

Once the decision is made and the strategy is introduced in the CRD, the user runs the model and can see the results of their decision. The results show the level of implementation obtained in each policy and the effectiveness of this implementation level. Furthermore, the total resources used and the level of resources that have been assigned to each policy are presented. Finally, the resilience level achieved in each of the resilience dimensions is stated in the results. For every four-year simulation period, the model alerts the user about the errors performed associated with precedence relationships. The tool identifies why the implementation of some policies is not effective and presents an effective solution. Thus, the user can learn about the precedence relationships and be able to prioritize among the policies when developing the strategy in terms of the time order in which the policies should be implemented in practice. Fig. 8 shows the interface of the results screen.

5. Integration of tools into a European Resilience Management Guideline for city resilience

Local planning for resilience needs to take into account commonly accepted concepts for climate change adaptation and sustainability, critical infrastructures development and social dynamics. However, a city is not just about managing sustainability or adaptation issues; the objective of local politics is to strive for satisfying human needs and improving the citizens' quality of life. When dealing with local planning for resilience, the individual or sectorial management of tasks and activities is often time-consuming, fragmented, and inefficient, and may lead to increased workload and poor results. In contrast, the re-organization and integration of existing practices and activities, plans and strategies under one steering wheel, accepted commonly by everyone working in the city –practitioners in municipal departments, decision-makers and politicians - may help systemize the work, boost the efficiency of resilience-related activities at city level and provide a multitude of positive outcomes for municipal practitioners and citizens.

The inclusion of all the tools into an integrated management system for resilience building at the local level, the so-called European Resilience Management Guideline (ERMG), directs all available resources towards well-defined goals and secures transparency and the democratic principles of decision-making. In this way, the cities are able to transform the effort of running several parallel management systems into a well-thought and easy-to-understand cyclical resilience building process. This process integrates all the tools that were described in the previous sections and combines them with easily transferred and replicable good practices that enhance local resilience planning. The ERMG, then:

- Provides guidance and consultancy services to cities and local governments in assessing their local resilience status
- Sets measurable targets together with local stakeholders, using the five SMR Resilience tools to help the city further build local resilience and progress within the maturity stages
- Defines an operational framework that provides guidance and aims

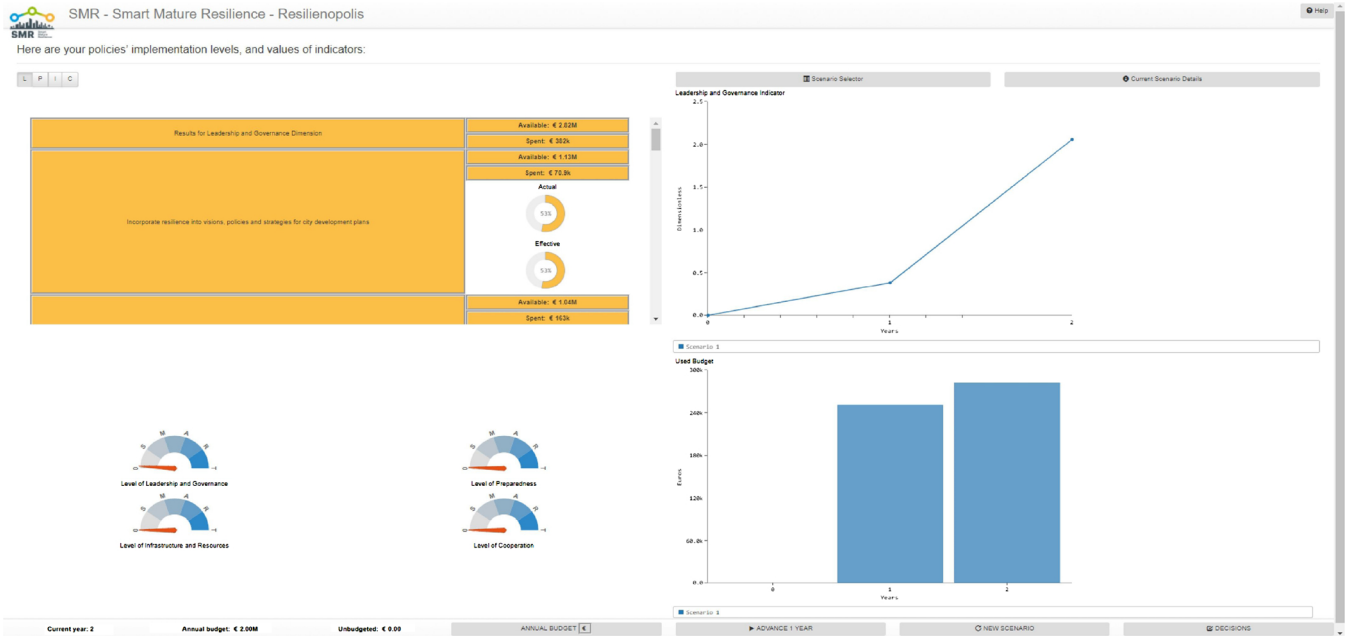

Fig. 8. The results screen where the resilience level achieved, the amount of allocated budget, and the implementation level achieved in each of the resilience policies is presented.

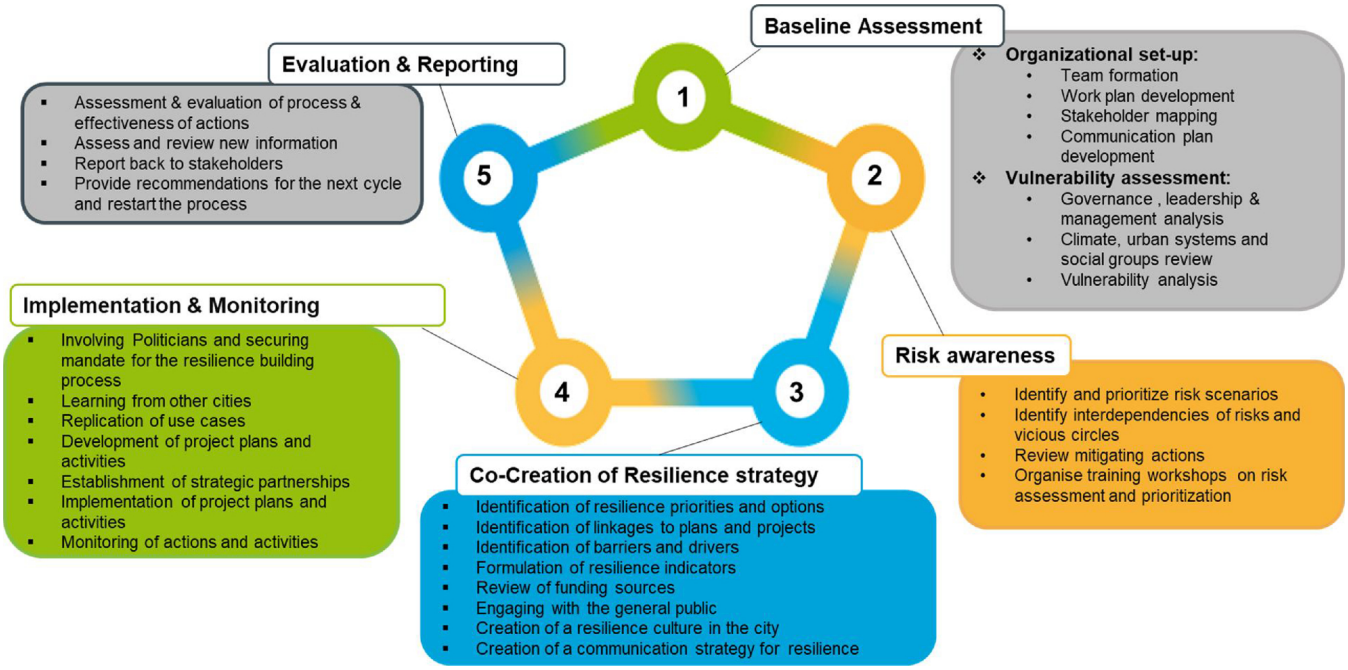
Baseline Assessment
Organizational set-up:
Team formation
Work plan development
Stakeholder mapping
Communication plan development
Vulnerability assessment:
Governance , leadership & management analysis
Climate, urban systems and social groups review
Vulnerability analysis
Risk awareness
Identify and prioritize risk scenarios
Identify interdependencies of risks and vicious circles
Review mitigating actions
Organise training workshops on risk assessment and prioritization
Co-Creation of Resilience strategy
Identification of resilience priorities and options
Identification of linkages to plans and projects
Identification of barriers and drivers
Formulation of resilience indicators
Review of funding sources
Engaging with the general public
Creation of a resilience culture in the city
Creation of a communication strategy for resilience
Implementation & Monitoring
Involving Politicians and securing mandate for the resilience building process
Learning from other cities
Replication of use cases
Development of project plans and activities
Establishment of strategic partnerships
Implementation of project plans and activities
Monitoring of actions and activities
Evaluation & Reporting
Assessment & evaluation of process & effectiveness of actions
Assess and review new information
Report back to stakeholders
Provide recommendations for the next cycle and restart the process
1
2
3
4
5

Fig. 9. The European Resilience Management Guideline: Operational steps for the resilience-building process.

at training and supporting municipalities and relevant stakeholders in implementing an integrated management system that enhances city resilience

The ERMG consists of five major steps repeated in annual cycles. The operational steps that constitute the ERMG are: (1) Baseline Assessment; (2) Risk Awareness; (3) Co-creation of a Resilience Strategy; (4) Implementation and Monitoring and (5) Evaluation and Reporting. Although this approach follows an annual cycle, full revision will be required once per election period – and preferably at the outset - unless the evaluation of achievements and results at the end of an annual cycle suggests reconsideration.

In addition to the five major steps, two cross-cutting elements need to be kept in mind throughout the steps of the cycle (see Fig. 9). These are: involvement and communication with stakeholders, and the general organizational setup of a resilience city team. From the very beginning of the cycle, it is important to carefully plan who will be involved in the resilience building process and what they can contribute. Getting as many relevant actors involved as possible will make the effort a common interest and that is thus more likely to succeed. The ''communication/cooperation with stakeholders'' element should also be considered as a cross-cutting element, as it is first needed stakeholder mapping in the baseline assessment and continues through the operational steps until the end, when the need to report back to stakeholders involved in the resilience-building process becomes necessary to ensure transparency and define the activities in the subsequent cycle (CHAMP Project, 2012).

The ERMG is better described as a journey in which one step follows the other, one in which cities and regions have different starting points. The benefits for cities that implement the ERMG to monitor their resilience building activities are the following:

- Increased awareness of climate change adaptation, critical infrastructure, urban resilience and sustainability
- Improved quality of management at a local level and across the various municipal departments
- Enhanced transparency and advanced monitoring action
- Increased trust in local governance
- Increased number of engaged citizens through co-creation activities
- Contribution to a sustainable and resilient economy and, last but not least
- Provision of better perspectives for a bottom-up inclusive EU, a goal that cities nowadays tend to promote and seek, especially in situations of austerity measures and increasingly limited resources

The ERMG was co-created and co-developed by all project partners, and was projected, tested and validated by 18 cities around Europe.

The involvement of external project stakeholders, such as other cities and resilience focused projects, to further validate and enhance the quality of the developed ERMG is ensured by the related standardization activities initiated by the project.

In recent years, standardization has become an important element in calls from the European Research Framework programs, such as FP7 and Horizon2020. For example, pillar three of the Horizon2020 Working Programme 2016–2017, Societal Challenges, referred to standardization in more than 40 calls (CCMC – CEN & CENELEC Management Centre, 2014). The SMR project is one of the few resilience related projects that included standardization activities, in which first a collection and analysis of relevant standards for city resilience took place (Smart Mature Resilience, 2016e). A standardization process for city resilience was applied (Lindner, Sarriegi, & Hernantes, 2018), including an assessment of the project's standardization potential by several criteria and the co-creative involvement of project externals, that resulted in the development of a standard related to the ERMG having the title 'City Resilience Development - Operational Guidance'. The objective of the standard is to define an operational framework for cities that provides guidance on local resilience planning and supports their efforts in building resilience. The standard is primarily targeted to policy and decision makers at city level and councillors working for climate adaptation and urban resilience, as well as to other city stakeholders working on resilience in their cities – for example, but not limited to, critical infrastructure managers, service providers, emergency services, individuals, media, non-governmental organizations, academic and research institutions, consultancies (CCMC – CEN & CENELEC Management Centre, 2017).

6. Conclusions and future work: standardization

The resulting ERMG proposes a detailed prescription about the way that the proposed strategic resilience tools should be used to enable a city to build local resilience and progress through the maturity stages.

Furthermore, the standardization of the tools and Guideline, undertaken as a co-creation process, also contributes to the resilience operationalization at the city level. It enhances the usability and the ease of implementing the Guideline and it enabled further input from other project external stakeholders such as representatives from other cities or other resilience focused research projects.

The developed CEN Workshop Agreement Series 17300 on 'City Resilience Development' are available in the database of the standardization system – providing a basis for the adoption of it in each European country and beyond. The uptake of project results on an international level within the standardization committee ISO/TC 268 Sustainable Cities and Communities is ongoing and will support the further dissemination and exploitation of the Guideline and tools. In particular, the under development ISO37123 Indicators for Resilient Cities includes an Annex that is directly linked to the Smart Mature Resilience project. In this annex, the included indicators relate and are mapped within the key stages of the resilience management cycle, as defined in the CWA17300:2018 City Resilience Development: Operational Guidance.

Thus, the transfer of the tools and Guideline into standards also will support further dissemination and exploitation of the project results. In more detail, the City Resilience Development: Operational Guidance framework assists municipal employees and consultants in assessing a city's (local) resilience status. The Operational Guidance consists of five steps that shall be repeated in regular cycles; typically, these cycles would be repeated annually, but this is subject to specific city needs.

When reviewing the standardization activities, it can be concluded that the end-user of the standard should be included in the development phase of the standards from the very beginning. During the standardisation process, the representatives of the participating cities acted as a focal point for the development of the standard on the Guideline as they will be the final users and they, therefore have an intrinsic motivation for participation.

However, it should be noted that the presented research has limitations, as the focus of the research was narrowed to the specific topics of the project and with 18 participating cities only a limited number of cities have contributed to the standards development of the Guideline.

Acknowledgements

The authors would like to thank the Smart Mature Resilience research project funded by the European Union's Horizon 2020 research and innovation program under grant agreement no. 653569.

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